# Review of Salmonid Resource Studies in Indian River and Indian Arm, and Enhancement Proposals for the Area

A.Y. Fedorenko and B.G. Shepherd

Salmonid Enhancement Program
Department of Fisheries and Oceans
1090 West Pender Street
Vancouver, British Columbia V6E 2P1

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by

A.Y. Fedorenko and B.G. Shepherd

Salmonid Enhancement Program
Department of Fisheries and Oceans
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

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## ABSTRACT

Fedorenko, A.Y. and B.G. Shepherd. 1984. Review of salmonid resource studies in Indian River and Indian Arm, and enhancement proposals for the area. Can. MS Rep. Fish. Aquat. Sci. 1769: 30 p.

The Indian River salmon stocks, particularly pink (Oncorhynchus gorbuscha) and coho (O. kisutch), have declined considerably since the 1970's, probably mainly due to overfishing and habitat degradation. This report reviews the status of the Indian River salmonid resource, describes local fisheries and other human activities in the area, and summarizes Department of Fisheries and Oceans studies and enhancement proposals.


Key words: Indian River, Indian Arm, salmonid enhancement, pink salmon (Oncorhynchus gorbuscha), coho (Oncorhynchus kisutch)


## RÉSUMÉ

Fedorenko, A.Y. and B.G. Shepherd. 1984. Review of salmonid resource studies in Indian River and Indian Arm, and enhancement proposals for the area. Can. MS Rep. Fish. Aquat. Sci. 1769: 30 p.

Les stocks de saumon de la rivière Indian, et plus particulièrement les stocks de saumon rose (Oncorhynchus gorbuscha) et de saumon coho (O. kisutch), ont connu une baisse considérable depuis les années 1970, ce qui s'explique principalement par la surpêche et la dégradation de l'habitat. Le présent rapport examine la situation des ressources en salmonidés de la rivière Indian, décrit les pêches locales et autres activités pratiquées dans la région et résume les études et propositions de mise en valeur du ministère des Pêches et des Océans.


Mots-clés: rivière Indian, bras Indian, mise en valeur des salmonidés, pêches, saumon rose (Oncorhynchus gorbuscha), saumon coho (Oncorhynchus kisutch)

## INTRODUCTION

Indian Arm lies inside Vancouver Harbour and is easily accessible to approximately 1.5 million people in the lower B.C. mainland (Fig. 1). This inlet is particularly attractive to recreational boaters because it is relatively sheltered compared to Georgia Strait and, as a result, is subject to growing pressure from sport fishermen. This pressure, combined with intensive interception commercial fisheries (M. Farwell, DFO, pers. comm.), and degradation of the Indian River watershed due to the B.C. Hydro right-of-way and extensive logging, appears to have resulted in a decline of fish stocks in the area. As a result, interest has been shown towards improving salmon production in Indian River and Indian Arm.

Between 1979 and 1982, the Department of Fisheries and Oceans (DFO) conducted three major programs in the area: operation of a chinook pilot hatchery on Indian River from 1979 to 1980, coho sea-pen rearing in Indian Arm from 1979 to 1981, and groundwater exploration in the Indian River watershed from 1972 to 1982.

This report describes the salmonid resource in the Indian River; evaluates river characteristics regarding fish production potential; summarizes DFO and other activities in the Indian River watershed and Indian Arm during the last decade; and discusses the options available for enhancing salmonid stocks in the area.

## DESCRIPTION OF THE AREA

Indian Arm is located just northeast of Vancouver and is a northern extension of Burrard Inlet (Fig. 1). This extension is a typical British Columbia fjord, about 22 km long and 1 km wide, with mountains bordering its sides and shielding it from prevailing winds.

The Indian River enters the northern end of Indian Arm (Fig. 1). The river begins at an altitude of approximately 720 m above sea level in the Fannin Range of the Coast Mountains, then flows for about 36 km in a southerly direction before entering Indian Arm.

Major tributaries of the Indian River are Meslillooet Creek, Brandt Creek, Forestry Creek and Hixon Creek. The total watershed area measures approximately 180 $km^2$ and is entirely mountainous with some peaks rising up to 1,950 m above sea level. The maximum runoff periods occur in May to June as a result of snow melt, and again in November to December as a result of high precipitation. An impassable series of 1 m to 2 m high falls is located approximately 10 km from the outlet (Fig. 2). Downstream of the falls, the valley is narrow except for delta areas at tributary confluences. These delta areas are generally quite small except for the Hixon Creek delta which measures about 60 ha. Access to the river is by boat from Deep Cove or by road from the Squamish area (Fig. 1); however, the road is generally not open in the winter due to snow at higher elevations. Logging roads provide good access to the river and its major tributaries for most of their length.

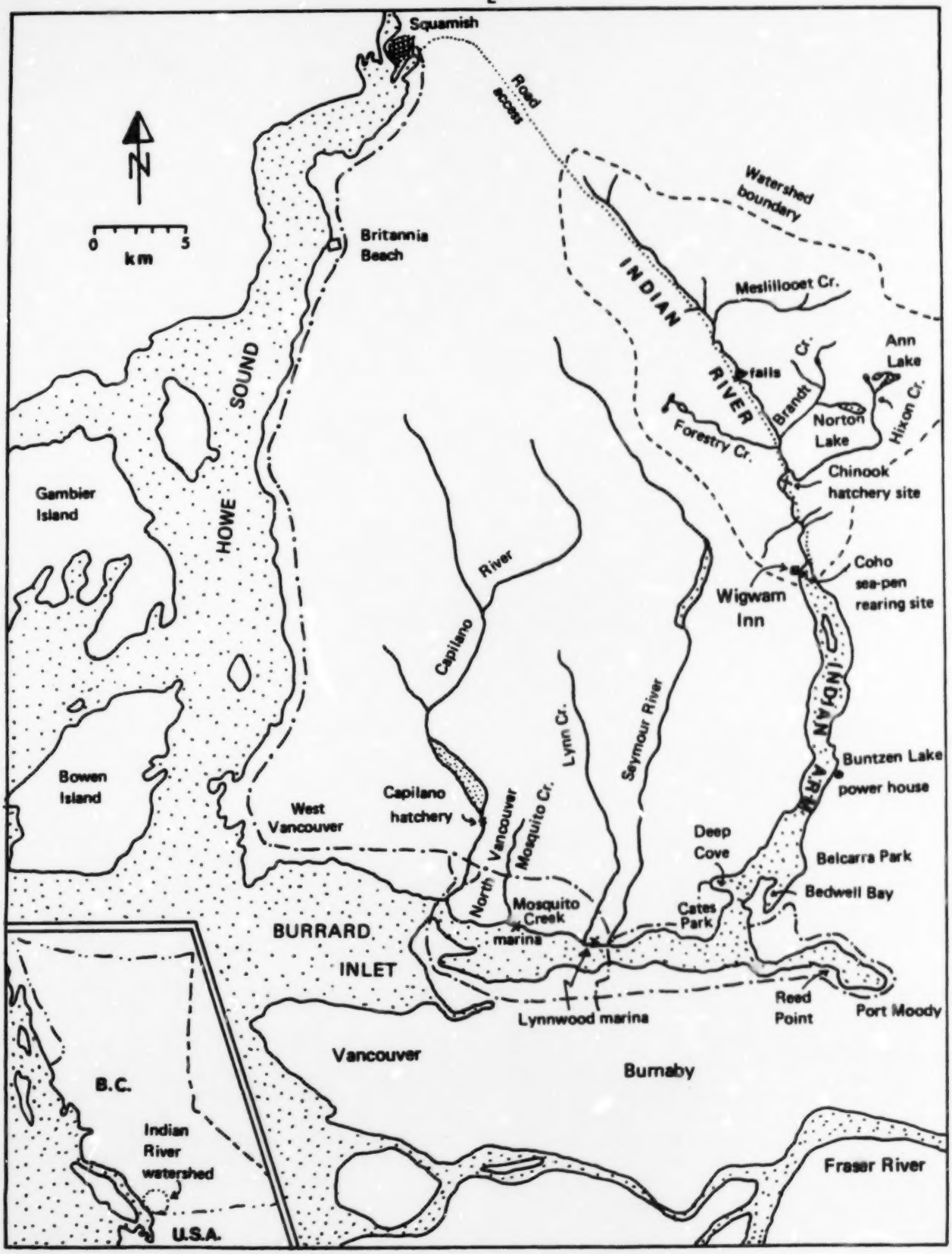


Fig. 1. Indian River watershed and the surrounding area.

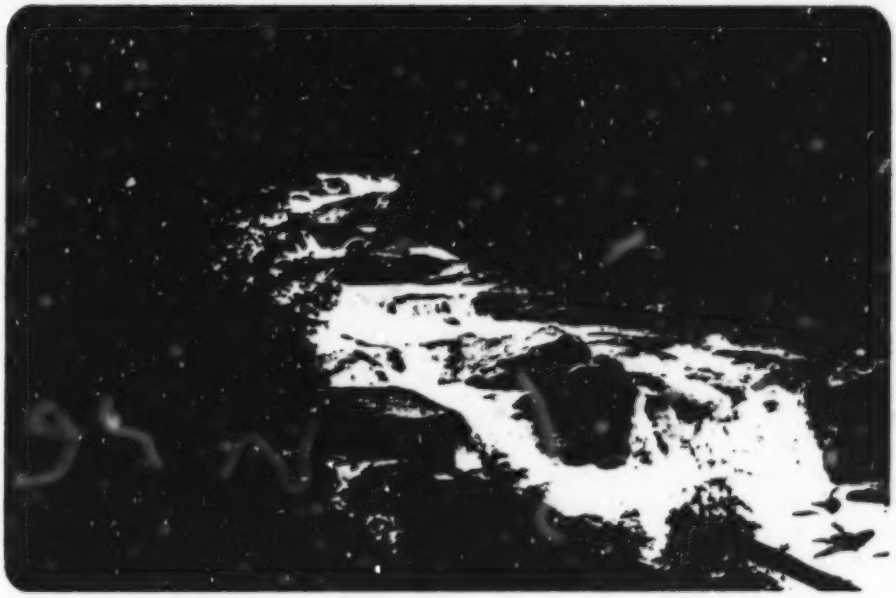

Fig. 2. The Indian River falls block further fish passage.

## DESCRIPTION OF SALMONID RESOURCE

### ADULT SALMON

#### Escapements

The Indian River is the only significant salmon spawning stream in Indian Arm and supports runs of chum, pink, coho and steelhead. Indian River, like other streams adjacent to Burrard Inlet, does not support a viable chinook run. However, very small populations of chinook and sockeye have been observed in the river since the 1970's. The recent establishment of a small chinook run in the Indian River may be the result of chinook transplants, but more likely is due to chinook straying from the nearby Capilano hatchery (Fig. 1). Populations of cutthroat trout and Dolly Varden are also present in the system.

The annual escapements of salmon to the Indian River are shown in Table 1. Until the late 1950's, over 100,000 salmon spawned annually in the Indian River during the dominant odd-year pink runs. During that period, the annual escapements averaged 85,000 odd-year pink salmon, 17,600 chum, 1,500 coho and 100 steelhead (both winter and summer runs). Escapements of most species began to decline in the 1960's. Mean annual escapements for the period 1971 to 1982 had dropped to 29,300 odd-year pink, 16,800 chum and 460 coho. Cutthroat trout populations are thought to be declining as well (Appendix 1).

The general decline of the Indian River salmon stocks is partly due to the intensive local and off-shore fisheries as well as to increased poaching during the spawning season. However, the continuing relatively high levels of pink and especially chum stocks are quite unique since these species have shown dramatic declines in most southern B.C. streams. One possible reason for the maintenance of these stocks in the Indian River may be the relatively low numbers of predators such as coho (Parker 1968, 1971; Beall MS 1972; Dunford MS 1975).

#### Timing of migration and spawning

Pink salmon spawn in Indian River from mid-September to October with a peak in late September. Chum salmon spawn from early October to December with a peak in late October to November. Coho have a similar timing to chum but may spawn until January. The small runs of sockeye and chinook show peak spawning in early September and mid-October respectively. Summer steelhead enter the Indian River in June and July, while winter steelhead enter from November to February. The latter fish show peak spawning in April and May.

#### Spawning distribution

Salmon in the Indian River spawn only in its lower 10 km since a series of falls prevents further fish passage (Fig. 1). Pink and chum salmon spawn primarily in the first 6 km of the mainstem from the river mouth to Forestry Creek, with very light concentrations of fish also observed up to the falls. Unlike pink salmon which utilize the main channel, chum salmon heavily utilize sloughs and tributaries. For example, in 1976 up to 5,000 chum spawners or 25% of that year's escapement were observed in Jack's Slough (Fig. 3; DFO,

Table 1. Estimated annual escapements of pinks, chum, coho, sockeye, chinook and steelhead into the Indian River, 1934-1982.[a]

| Year | Pink | Chum | Coho | Sockeye | Chinook | Steelhead |
|---|---|---|---|---|---|---|
| 1934 | 500 | 10,000 | 500 | -[b] | - | N/A[c] |
| 1935 | 100,000+ | 5,000 | 1,000 | - | - | 300 |
| 1936 | 50 | 100,000+ | 500 | - | - | 100 |
| 1937 | 100,000+ | 20,000 | 100 | - | - | 100 |
| 1938 | 100 | 10,000 | 3,500 | - | - | 50 |
| 1939 | 100,000+ | 3,500 | 500 | - | - | 50 |
| 1940 | 50 | 3,500 | 3,500 | - | - | 50 |
| 1941 | 100,000 | 50,000 | 3,500 | - | - | 50 |
| 1942 | 50 | 50,000 | 3,500 | - | - | 50 |
| 1943 | 5,000 | 2,000 | 500 | - | - | 50 |
| 1944 | - | 1,000 | 1,500 | - | - | 50 |
| 1945 | 100,000 | 3,500 | 1,000 | 50 | - | 50 |
| 1946 | 25 | 3,500 | N/A | - | - | 50 |
| 1947 | 75,000 | 15,000 | 750 | 25 | - | 75 |
| 1948 | - | 15,000 | 1,500 | - | - | 75 |
| 1949 | 10,000 | 3,500 | 1,500 | 25 | - | 75 |
| 1950 | - | 3,500 | 1,500 | - | - | 400 |
| Mean (1934-1950) | 85,000[d] | 17,600 | 1,500 | - | - | 100 |
| 1951 | 75,000 | 35,000 | 3,500 | - | - | 750 |
| 1952 | 75 | 35,000 | 3,500 | - | - | 400 |
| 1953 | 100,000+ | 1,500 | 1,500 | - | - | 400 |
| 1954 | 200 | 35,000 | 1,500 | - | - | 400 |
| 1955 | 75,000 | 3,500 | 3,500 | - | - | 400 |
| 1956 | - | 1,500 | 1,500 | - | - | 400 |
| 1957 | 125,000 | 3,500 | 1,500 | - | - | 400 |
| 1958 | - | 15,000 | 750 | - | - | 200 |
| 1959 | N/A | N/A | N/A | N/A | N/A | N/A |
| 1960 | - | 4,000 | 1,500 | - | - | 400 |
| 1961 | 67,800 | 2,500 | 3,500 | - | - | 200 |
| 1962 | - | 3,500 | 400 | - | - | 400 |
| 1963 | 200,00 | 3,000 | 1,500 | - | - | 400 |
| 1964 | - | 5,000 | 3,500 | - | - | 200 |
| 1965 | 35,000 | 3,500 | 400 | - | - | 400 |
| 1966 | 75 | 3,500 | 1,500 | - | - | 200 |
| 1967 | 7,500 | 3,500 | 1,500 | - | - | 200 |
| 1968 | - | 15,000 | 750 | - | - | 400 |
| 1969 | 7,500 | 15,000 | 400 | 25 | - | 200 |
| 1970 | - | 15,000 | 750 | 25 | - | 200 |
| Mean (1951-1970) | 77,000[d] | 10,700 | 1,700 | - | - | 340 |
| 1971 | 35,000 | 7,500 | 750 | 25 | - | 200 |
| 1972 | - | 35,000 | 400 | - | - | 200 |
| 1973 | 35,000 | 35,000 | 750 | - | - | 200 |
| 1974 | - | 7,500 | 750 | - | - | 200 |
| 1975 | 22,000 | 12,000 | 200 | 75 | - | 150 |
| 1976 | - | 20,000 | 200 | - | - | - |
| 1977 | 22,000 | 14,000 | 500 | 25 | 25 | 25 |
| 1978 | - | 7,000 | 150 | 7 | 6 | 25 |
| 1979 | 22,000 | 7,500 | 280 | 12 | 180 | 50 |
| 1980 | - | 15,000 | 300 | 25 | 50 | 150 |
| 1981 | 40,000 | 17,500 | 800 | 8 | 20 | 80 |
| 1982 | - | 24,000 | 450 | N/A | 50 | 75 |
| Mean (1971-1982) | 29,300[d] | 16,800 | 460 | 25 | 30 | 110 |
| Overall mean (1934-1982) | 67,300[d] | 14,700 | 1,300 | - | - | 200 |

[a] Sources: DFO Indian River spawning files and Marshall et al. (1976).
[b] None observed.
[c] Not available.
[d] Odd years only.

unpublished data). Coho and steelhead spawn mainly in the upper part of the mainstem above Forestry Creek up to the falls. All of the above species have been observed to spawn in Hixon Creek.

JUVENILE SALMON

During the spring of 1977, limited fish trapping using Gee minnow traps was conducted in the Indian River mainstem (DFO, MS 1977). The traps were baited with coho salmon roe and were set randomly overnight in various locations throughout the lower 10 km of the mainstem. Traps were set in sites that appeared to be physically favourable for fish rearing. These included Jack's Slough, which is a side channel to the mainstem approximately opposite the mouth of Hixon Creek; a large brackish bay about 180 m upstream from the Indian River outlet; and quiet, sheltered backwater areas in the lower 5 km of the mainstem (Fig. 3). Fish captured were identified to species and sampled randomly for fork length and scales.

The trapping effort, number of fish captured by area and mean length of coho juveniles are shown in Table 2. A total of 199 coho juveniles and 20 prickly sculpins (Cottus asper) were captured in the survey. The 49 coho juveniles sampled for length averaged 72 mm and the five coho sampled for scales were all age 0+.

This trapping study obviously did not determine the total species present but probably indicated the relative abundance of coho juveniles in various sections of the Indian River. Jack's Slough and the sheltered backwater areas in the lower 5 km of the river appeared to be the most densely populated sites and are probably important juvenile rearing habitats. It is suspected that in addition to pink and chum fry, some coho juveniles could emigrate soon after hatching to estuarine areas in Indian Arm to rear. This possibility is also suggested by frequent sightings of large flocks of ducks feeding near the river mouth in spring and early summer.

## FISHERIES

RECREATIONAL AND COMMERCIAL FISHERY

Indian Arm has limited private and residential developments along its west and east shorelines and is within easy boating distance of Deep Cove, Reed Point, Lynnwood and Mosquito Creek Marinas, as well as a number of public launch sites (Fig. 1). During spring, summer and fall, boat traffic is heavy and ranges from large power cruisers to small outboards and canoes; sailboat traffic is minor.

The limited recreational fishery in the inlet includes jigging for cod along the rocky cliffs, groundfish catches reported in Bedwell Bay and Belcarra Park (Fig. 1), and some winter fishing for chinook and sea-run cutthroat trout. In addition, there is recreational and minor commercial crabbing in Bedwell Bay and near Belcarra and Cates Parks (Fig. 1), as well as trolling for salmon during Indian Arm spawning runs. The odd-year pink runs attract a small sport fishing fleet to the mouth of the Indian River during August.

Table 2. Numbers of minnow traps used, catch by species and mean length of coho juveniles by area sampled, Indian River, spring 1977 (n = sample size).

| Area (Fig. 3) | No. traps | No. sculpins | No. coho | No. coho per trap | Coho length (mm) | |
|---|---|---|---|---|---|---|
| | | | | | n | Mean ± 1 S.D. |
| Mainstem above bridges | 4 | 3 | 1 | 0.3 | 1 | 64 |
| Jack's Slough | 14 | 4 | 122 | 8.7 | 30 | 72.3 ± 9.1 |
| Slackwater below bridges | 8 | 0 | 75 | 9.4 | 17 | 72.4 ± 6.2 |
| "Brackish Bay" | 14 | 13 | 1 | <0.1 | 1 | 68 |
| Total | - | 20 | 199 | - | 49 | 72.0 |

Unlike Indian Arm, the Indian River generally is not used for recreational fishing despite its considerable potential for trout and salmon angling. This is due largely to its poor access. Power boats cannot ascend past the river mouth and the only land access is a four-wheel drive road from Squamish through rough and mountainous terrain (Fig. 1). However, this road seems popular for four-wheel drive campers. During weekends between July and October in recent years, Fishery Officers have counted up to 25 vehicles along the river and up to 50 boats at the river mouth (S. Roxburg, DFO, pers. comm.).

It seems therefore, that only part of the full recreational potential of the Indian Arm and Indian River is being achieved at present.

NATIVE FOOD FISHERY

The native food fishery on Indian River is limited to that of the Burrard Indian Band, and is situated near the river mouth. The annual catch from this fishery has been reported to DFO only intermittently (N. Shubert, DFO, pers. comm.):

| Year | Catch |
|---|---|
| 1940 | 1000 (chum) |
| 1951 | 300 (species not given) |
| 1952 | 100 ( " " " ) |
| 1953 | 95 ( " " " ) |
| 1965 | 245 ( " " " ) |
| 1966 | 70 ( " " " ) |
| 1967 | 510 ( " " " ) |
| 1968 | 13 ( " " " ) |
| 1971 | 385 (pink, coho, chinook and steelhead) |

Despite the relatively large odd-year pink runs to the Indian River, this species generally is not favoured as a food source.

ACTIVITIES BY THE DEPARTMENT OF FISHERIES AND OCEANS

MINOR ACTIVITIES

In 1961, the DFO erected a fish counting weir and holding facilities on the Indian River approximately 2 km upstream from the river mouth. These structures were built as part of a joint international program for the study of pink salmon and were used in 1961 and 1963 for adult enumeration and egg-taking. The facilities were partially washed out by floods in 1963 and were totally removed in 1973.

Fish transplants have been conducted in the Indian Arm area since 1959. During 1959, 1961 and 1963, Indian River pink salmon were transplanted to Robertson Creek (Lim and Barrett 1982). In March 1966, 42,000 chinook fry from the Big Qualicum River, Vancouver Island, were transplanted to the Indian River and released in two lots 8 km and 12 km upstream from the river mouth, in an attempt to establish a run of this species (Lister MS 1968). Mean size of the

transplanted fry was 42 mm and 0.5 g. This transplant was considered unsuccessful since the fry were released at a single point during flood conditions and appeared to have been flushed out from the system. However, in the early 1970's, a local trapper caught in Indian River a large chinook which may have been one of the transplant returns or a Capilano stray.

On August 23, 1974, 8,782 yearling coho (1972 brood) with mean weight of approximately 43 g were transported from the Capilano hatchery for direct release in Indian Arm in the vicinity of the Buntzen Lake powerhouse (Fig. 1). All fish released were adipose fin-clipped and coded wire nose-tagged using code 02-01-01. Immediate mortality was considered minimal and an estimated 8,500 coho smolts survived the transplant operation. A total of 10 tagged coho adults were recovered from this transplant, of which half came from sport catches in Bedwell Bay (Fedorenko and Perry 1984).

In early April 1981, 150,000 1.5 g untagged chinook fry from the Capilano hatchery were scatter-released by helicopter throughout Indian River. No further scatter-releases of chinook were made in the area since surplus chinook fry were not available from the Capilano hatchery.

During 1976 and 1977, DFO staff (Fraser River-West Coast Vancouver Island Division) conducted biological surveys on the Indian River in order to ascertain the success of a potential hatchery. The physical parameters of the Indian River were assessed by walking the river from its outlet to the falls about 10 km upstream. The segment above the falls was also surveyed briefly at that time in order to assess its salmonid production potential. Water quality and temperature data were also collected at that time (Fedorenko and Shepherd 1984). The first 10 km of the Indian River accessible to salmonids were felt to offer considerable high quality spawning and rearing habitat. For purposes of description, the useable river length was divided into four generally homogeneous sections A to D (Fig. 3).

Section A stretches from the river mouth to approximately 1.2 km upstream. Generally of deltaic character, the water in this section is brackish and under direct tidal influence. The river meanders sluggishly through lush eel-grass fields which are frequented in the springtime by waterfowl. Substrate consists of a high percentage of sand with some coarse (5 cm - 8 cm) gravel also present.

Section B, approximately 0.8 km long, maintains the low gradient of the previous section but differs primarily with respect to a straightening and deepening of the river channel. The sandy substrate gives way to a fine gravel, but sand still composes up to 50% of the total. Deciduous cover is abundant and many quiet pool areas are present.

Section C is 5.2 km long and encompasses the bulk of the prime spawning grounds. The channel ranges in width from approximately 21 m to over 46 m and meanders from side to side, creating many side channels and undercut banks. Pools and riffles occur throughout this section with equal frequency. The substrate is predominantly coarse (5 cm - 8 cm) gravel, with larger boulders occurring occasionally. Several old, dewatered side channels were observed; these were the result of blockage created by logging debris which built up at

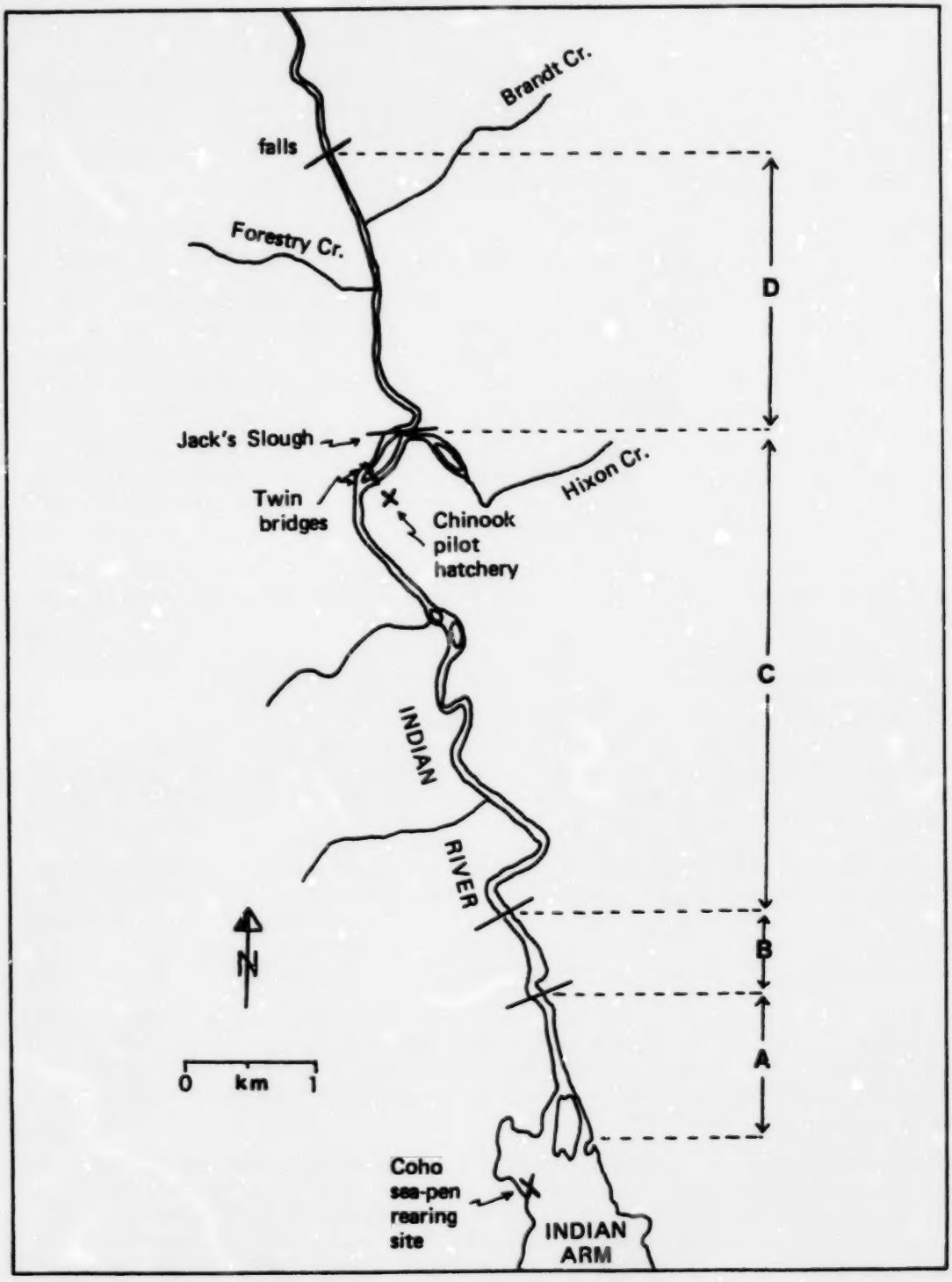


Fig. 3. Indian River showing sections A -D.

the point where the river formerly entered. Coniferous and deciduous covers occur in equal quantities and provide good rearing cover throughout this section. Hixon Creek enters the mainstem near the upper end of this section.

Section D is approximately 2.4 km long and terminates at a series of 1 m to 2 m high falls which have historically prevented further fish passage. The gradient increases considerably over this section, at times approaching 5% but usually nearer to 2%. The bottom material consists largely of boulders greater than 20 cm, with only occasional stretches of gravel suitable for spawning. The ratio of pool to riffle is quite low throughout. Stream cover remains good but side channels occur far less frequently than further downstream. Forestry and Brandt creeks are the major tributaries in this section; the former has good gravel areas near its mouth where spawning coho have been observed.

The river section upstream from the falls to the junction of Meslillooet Creek, the largest of the Indian River tributaries (Fig. 1), is approximately 6 km long and has physical parameters which appear to be favourable for salmonid production. Only a 1.2 km segment immediately upstream of the falls is considered to be unsuitable for fish production. This short stretch is composed largely of bedrock and consists primarily of a series of 0.6 m to 0.9 m high falls amongst large boulders. The remaining upper river segment is quite similar to the prime spawning area further downstream. The river channel widens to over 61 m at times and 5 cm to 8 cm gravel sizes are prevalent. Pools and riffles occur with equal frequency and some side channels are present. The greatest detriment to this area is the denudation of a considerable portion of the west bank for the B.C. Hydro right-of-way and the main road, both of which parallel the river very closely for approximately 3 km. Only minimal stream cover remains in much of that area.

## MAJOR ACTIVITIES

### Chinook pilot hatchery on Indian River, 1979-1980

In 1979, DFO received an unsolicited proposal from Indian Arm Salmon Ltd. to construct and operate a pilot hatchery on the Indian River in order to test the feasibility of a major hatchery. The two existing test wells in the Hixon Creek delta were resampled by DFO Salmonid Enhancement Program (SEP) staff that summer for water quality and a chinook pilot hatchery was constructed. The SEP Engineering Department designed the hatchery, constructed the aeration tower, and provided assistance and partial funding of construction for the project. The hatchery operated under contract to SEP from November 1979 to June 1980, when it was closed due to lack of funds.

The pilot hatchery is described in detail by Fedorenko and Shepherd (1984). Approximately 250,000 chinook eggs were transported from the Capilano hatchery to the Indian River pilot hatchery in November 1979. The eggs were incubated in Heath trays. The fry were reared up to 2.4 g in indoor troughs, then transferred to an outdoor rearing pond, and released to the river at an average size of 3 g to 6 g. The overall egg-to-ponding survival was 91%; the overall egg-to-release survival was 78%. Of the approximately 194,300 chinook smolts released in June, 102,500 were tagged with tag code 02-18-39. Adult returns are not yet complete.

Fry mortality incurred during rearing was only a few percent of the total fry and was attributed mainly to coagulated-yolk disease. This disease was tentatively linked with the very low hardness (2-5 mg/l as $CaCO_3$) and supersaturation (up to 106% $N_2$) of the groundwater supply source. In view of the low rearing mortalities, the juvenile production part of this project was considered to be successful. However, it must be cautioned that under intensive fish culture conditions, the marginal water quality at Indian River may result in severe rearing problems and mortalities.

Coho sea-pen rearing in Indian Arm, 1979-1981

During 1979 to 1981, the Indian Arm Salmon Ltd. also conducted a coho sea-pen rearing study in Indian Arm under contract to SEP. This project was undertaken to determine the feasibility of sea-pen rearing in Indian Arm. A secondary goal of the coho project was to enhance local sport fishing through delayed release of smolts, similar to methods used to enhance Puget Sound sport fishing (Washington Department of Fisheries 1971).

The coho pilot project is described in detail by Fedorenko and Perry (1984). In the fall of 1979 and 1980, approximately 120,000 and 100,000 coho fry respectively were transported from the Capilano hatchery to sea-pens in Indian Arm. Fry were reared for up to 11 months, then released the following year in three differentially tagged groups of different sizes on three separate dates (May, June and July). Approximately 91,000 and 85,000 coho smolts were released in 1980 and 1981 respectively. Rearing mortalities were partly attributed to bacterial kidney disease (BKD). The severity of this disease increases with increased spring temperatures and the optimum incubation temperature for the BKD disease organism is 11° C (Wood 1974). This temperature was reached in May during both years of coho rearing in Indian Arm (Fedorenko and Perry 1984). No effective therapeutic agents exist for combating BKD, but an OMP diet containing cottonseed meal may help reduce fish susceptibility to this infection (Wood 1974). Sea-pen rearing survivals averaged 76% and 85% for the 1978 and 1979 broods respectively.

The estimated smolt-to-adult survivals for the respective broods, based on tag recoveries, were 10.2% and 9.0%. The July release groups had the lowest marine survival and smallest adult size but both June and July groups contributed more to the local Georgia Strait sport fishery compared to the May group. A local sport fishery on resident coho failed to develop since no fishing benefits were documented for Indian Arm alone. In addition, the smolt-to-adult survivals of Indian Arm pen-reared coho were lower than those experienced using other fish culture methods in B.C. such as freshwater rearing in a hatchery (Fedorenko and Perry 1984).

Groundwater exploration program in Indian River watershed, 1972-1981

In 1971 and 1972, Underwood McLellan and Associates Ltd. conducted a hatchery site feasibility study on the Indian River for the Fisheries Service. They selected the Hixon Creek delta as a potential hatchery site (Fig. 3) and

drilled and tested two wells in that area in 1972 (Underwood McLellan and Associates Ltd.(MS 1972).

In an attempt to find a more suitable groundwater source for fish culture than that available at the Hixon Creek delta, further well drilling and groundwater testing were conducted between 1981 and 1982 at a new site located about 2 km upstream of the previous site. This site was chosen mainly due to its proximity to potential gravity supply of surface water from Indian River. Concurrently, preliminary design of a multi-species hatchery was developed to the site-layout stage. The proposed production goals included 400,000 pink, chum, chinook and coho adults, and a limited production of cutthroat and steelhead adults (see section below on enhancement proposals).

The groundwater exploration program in Indian River watershed is described in detail by Fedorenko and Shepherd (1984). The groundwater from the nine wells tested in the Indian River watershed between 1972 and 1982 was considered to be unsuitable or only marginally suitable for fish culture purposes. This water has extremely low buffering capacity (4-15 mg/l as $CaCO_3$), extreme softness (2-15 mg/l as $CaCO_3$), low pH (5.3 - 6.9), dissolved gas problems and in some cases, higher than recommended concentrations of copper, iron and zinc.

Water from wells No. 7b and No. 9 has a relatively better water quality and could be treated physically with mineral enrichment, such as a $CaCl_2$ drip system, and aeration to provide satisfactory water quality. Mineral enrichment of hatchery water during rearing has been tried apparently successfully in the Dworshak National Fish Hatchery in Idaho where extremely soft water rearing conditions were linked with increasing steelhead mortalities prior to smoltification (Olsen and Bradley, pers. comm., 1980 Northwest Fish Culture Conference). However, such technological and logistical complexity may cause problems at an isolated site such as the Indian River.

The Indian River surface water is also only marginally suitable for fish culture purposes. This is largely due to its extremely low buffering capacity (2-14 mg/l as $CaCO_3$), extreme softness (3-17 mg/l or $CaCO_3$) and slightly acidic water (mean pH 6.8, range 6.0 - 7.4).

## RESEARCH PROJECTS

Research projects have also been conducted on Indian River. In the fall of 1982 approximately 100 chum spawners, and in the fall of 1983 approximately 100 pink spawners were captured in the Indian River for an experiment in stock identification using electrophoretic tissue analysis. This research is being conducted by Dr. T. Beacham at the Nanaimo Biological Station (M. Farwell, DFO pers. comm.)

# OTHER ACTIVITIES IN THE INDIAN RIVER WATERSHED

## MINING

Numerous mineral claims have been staked in the uppermost Indian River watershed and in the area located directly east up to Britannia Beach on Howe

Sound (Fig. 4). The first Indian River claims were made in the early 1900's with additional claims staked further down the valley in later years (Camsell 1918). The Anaconda Company Ltd. presently holds some 13 $km^2$ of mineral claims in the area.

Numerous early geological surveys conducted in the upper Indian River Valley indicated the presence of copper, zinc, and traces of silver and gold (Camsell 1918). Prospecting in the Indian River headwaters continued into the 1980's with further discoveries made of copper, zinc and lead mineralization (Lisle 1980). Current geological surveys include exploration for molybdenite; a camp was established in 1983 at the junction of Stawamus Valley and headwaters of Indian River (C. Chestnut, BCIT, pers. comm.).

A once active copper mine is located approximately 15 km west of the Indian River headwaters at Brittania Beach on Howe Sound (Fig. 4). This mine began operating in 1899 and produced mostly zinc rather than copper (Hoos and Vold 1975). The mine, which is presently operated by the Anaconda Company Ltd., closed in 1974 except for the copper precipitator (Hoos and Vold 1975).

## LOGGING

During the 1920's, the Indian River was used for log driving. In 1959, Canadian Collieries Resources Ltd. (now Weldwood of Canada) constructed a logging road along the eastern bank of the Indian River from tidewater to the falls some 10 km upstream. Logging commenced in 1960 and continues actively throughout the watershed. The main logging camp is located about 0.6 km upstream from the river mouth. At present, most of the Indian River valley is taken up by timber berths owned by Weldwood of Canada.

## OTHER ACTIVITIES

In 1969, the B.C. Hydro installed transmission lines along the Indian River. The 60 m wide right of way runs close to the river and crosses it at numerous locations. The clearing for a hydro right-of-way and the extensive logging operations have resulted in virtually complete deforestation of major areas within the Indian River watershed.

Aside from two trapper's cabins, there is no other development or privately-owned land in the river valley. In contrast, much of the Indian Arm foreshore is privately owned, with the Wigwam Inn (Fig. 1) periodically open to tourists.

Another potential user group in the area is the Greater Vancouver Water District. The GVWD has an existing water licence which would allow them to divert much of the flow in Hixon Creek into the Coquitlam watershed. The District is currently (1984) applying for a permit to divert approximately 2.8 $m^3$ (100 cfs) of water from Hixon Creek into the Coquitlam watershed (B. Field, DFO, pers. comm.). Such possible diversion of the creek would no doubt affect Indian River water quality and flow, and therefore also the fishery resource below the confluence.

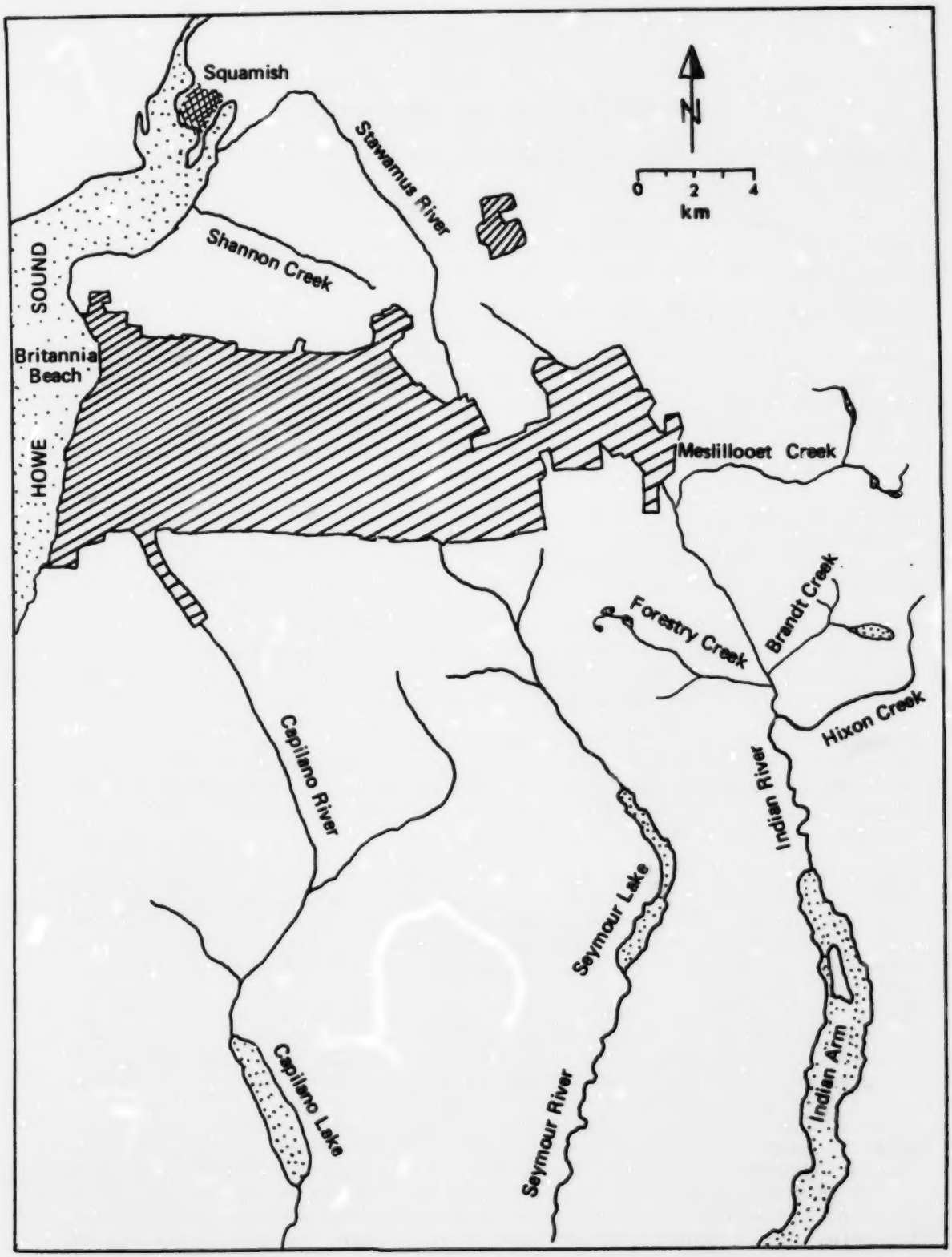


Fig. 4. A guide to the positions of located mineral claims and Placer Mining Leases (hatched area), July 19[illegible] (Dept. Mines and Petroleum Resources).

## ENHANCEMENT PROPOSALS AND OPPORTUNITIES

Escapement records (Table 1) suggest that the productivity of salmon in the Indian River is well below the historical levels. In the 1930's to 1950's, the Indian River was capable of supporting annual salmonid runs of over 100,000 fish. This capability no doubt has decreased with deforestation of the watershed. In order to increase fish productivity in the Indian River, the following measures have been proposed over the last decade:

1. Installation of incubation boxes, possibly in Jack's Slough located near the Hixon Creek delta (Fig. 3). This slough appears to be very productive since it is heavily utilized by chum spawners and has a high concentration of rearing coho juveniles. In addition, this channel can be relatively easily partitioned off from the rest of the system to be managed for capture of brood stock. The channel also has a relatively warm groundwater source; a groundwater stream enters Jack's Slough at about the halfway point (see Fedorenko and Shepherd(1984)for temperature data).

2. Annual maintenance and debris removal to open side channels which at present receive little or no water during low flows. For example, in mid-January 1977, salmon redds at the upper end of Jack's Slough were dewatered as a result of a slight drop in river level (DFO MS 1977).

3. Reduction of poaching in the area by regular patrolling by Fishery Officers. The public is able to reach the Indian River with increasing ease largely because of sophisticated all-terrain vehicles. Current DFO funding is insufficient to provide regular patrolling of the area.

4. Breaching of the waterfall obstruction located 10 km upstream from the river mouth either by rock blasting or by construction of a fish ladder. This would expose an additional 20 km to 25 km of prime spawning and rearing habitat for sea-run fish, and provide more angling water to steelhead and cutthroat anglers (Appendix 1).

5. Construction of a hatchery facility on Indian River to propagate pink, chum, chinook, coho, steelhead and cutthroat. The SEP has proposed the following target adult numbers for each species (Appendix 2): 200,000 pink, 100,000 chum, 50,000 chinook, 50,000 coho, 10,000 cutthroat and 1,000 steelhead. A possible release of 100,000 unfed fry of each of cutthroat and steelhead was also considered.
   Due to questionable groundwater quality for fish culture, the above species mix may have to be altered to favour pink and chum production (see below). Also, any proposed species mix must first be approved by the DFO Management Group which has to decide which type of target fishery (commercial, sport, native or mixed) is suitable for this area (Appendix 3).
   Production of steelhead in the hatchery should improve the winter run and possibly summer run, and provide a year-round uncrowded fishery (Appendix 1). Propagation of cutthroat juveniles in the hatchery should provide a source of smolts and fry to outplant to streams on Indian Arm and the North Shore of Vancouver; these outplants would primarily enhance marine beach fisheries for cutthroat trout which are gaining in popularity around

Vancouver (Appendix 1). The production of steelhead and cutthroat trout in the Indian River hatchery is particularly favoured since other means of improving these stocks, for example by employing the Capilano hatchery and the BCIT facility on the Seymour River, are not considered to be sufficient (Appendix 1).

In order to reach target sizes by spring release dates, a hatchery facility on Indian River would have to utilize warm water sources during winter months (Fedorenko and Shepherd 1984). Therefore, the feasibility for a hatchery is strongly dependent on finding a suitable groundwater supply for fish culture or an adequate means to treat the available groundwater sources.

Studies of the Indian River surface and groundwater quality, and the chinook pilot hatchery both indicate that the soft, acid water in the Indian River watershed may not be suitable for extended rearing of salmonid juveniles (Fedorenko and Shepherd 1984). Therefore, the culture of chinook, coho and trout may be difficult. However, the incubation and short-term rearing of pink and chum at Indian River would be more feasible and the benefits of enhancing these stocks should be considered.

6. Chinook and coho production targets for the Burrard Inlet area may be able to be achieved through expansion of existing facilities at Capilano and Seymour rivers. This would allow for annual chinook and coho fry outplants to the local rivers thus precluding the need to deal with these species at Indian River (Appendix 3).

7. Propagation of chum salmon and possibly coho (coho rearing may be problematic due to diseases related to high water temperatures) in Indian Arm through sea-pen rearing. This program would operate jointly with the river coho and chinook fry outplants.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the water quality results from groundwater and surface water testing in the Indian River watershed, no suitable water for fish culture activities exists in this area without specific water treatment. However, although the problems of nitrogen supersaturation and oxygen undersaturation in the groundwater can probably be resolved with an improved stripping/aeration tower, the exceedingly low water hardness in both the surface water and groundwater is difficult to rectify without adding considerable technological complexity. Observations on the chinook pilot hatchery further suggest that it is unlikely that a major multi-species hatchery would be successful on the Indian River. Given the marginal water quality for fish culture in this watershed, a more viable approach to salmonid enhancement would be a facility that concentrated on species requiring little or no freshwater rearing, such as pink and chum.

In view of the above, a number of short-term initiatives are recommended in order to help choose the long-term fish production strategy for the Indian River/Indian Arm area:

1. Operate a second pilot facility on the Indian River to determine long-term variations in groundwater chemistry and temperature and its suitability for the culture of pink or chum salmon. Wells No. 7b and No. 9 at the new site are recommended as the best trial candidates. The pilot facility should incorporate a mineral enrichment system to increase hardness, and aeration to bring dissolved gases to saturation levels.

2. If construction of a pilot facility is not possible, it is recommended to conduct long-term (20 to 30 days) pumping and water quality testing at a selected groundwater source (wells No. 7b or No. 9) prior to the introduction of fish. This, however, is a costly proposition and one that would yield less information than a pilot hatchery.

3. Gather additional temperature data at selected Indian River and groundwater sites to allow an assessment of seasonal temperature variations as related to design requirements (due to flooding condition, thermographs installed in the Indian River must be protected).

4. Conduct regular sampling of Indian River surface water for suspended solids, ensuring that storm events are monitored.

5. Install a continuous water level recorder in the Indian River and the selected groundwater source in order to assess the magnitude and nature of groundwater level fluctuations in relation to river flow.

6. Assess potential problems with herbicides and pesticides used for vegetation control on the B.C. Hydro right-of-way.

7. Examine the implications of the proposed partial diversion by Greater Vancouver Water District of Hixon Creek water to the Coquitlam watershed.

8. Develop a program for enhancing the Indian Arm sport fishery by releasing hatchery smolts reared in freshwater into Indian Arm.

9. Obtain a finalized decision from the DFO Management Group regarding the major client group to be served, species mix and production targets in the enhancement of the Indian River and Indian Arm salmonid resource.

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Appendix 1. Indian River Federal Salmonid Hatchery, B.C. Fish and Wildlife Branch memorandum, Nov. 6, 1980.

SUBJECT: Indian River Federal Salmonid Hatchery

It now appears that this facility will come on line fairly soon. According to Al Lill (GWG meeting Oct. 6/80) Fisheries and Oceans have done a pilot feasibility and the site looks very good (water quantity & quality is no problem). Al wants to put together a package that will have high production capability (as I understand the higher the production at this site the better the cost benefit picture. Funds for a major facility are still uncertain). A number of sites that could accommodate a major facility are now being investigated.

The purpose of this memo is to prepare you for probable near future provincial fish culture input to this facility design and to clarify enhancement goals for steelhead and sea-run cutthroat. Some details are:

(1) Production Goal - steelhead - 25,000 smolts (1,000 adults)
- cutthroat - 40,000 smolts (10,000 adults)

(Additional fry production for stocking to underused habitat would also be required).

(2) Number of different stocks - cutthroat, winter run steelhead, summer run steelhead. Winter runs enter in January and peak in April/May (there is a good surge of fish at this time). These winters are large fish. Run at present is in decline and is small to moderate in size (200 fish?). Summer runs are very small fish (3-4 lbs) which enter in June/July. Run is in decline and amounts to about 50 fish. Cutthroat are in sharp decline with run size unknown.

(3) Importance of enhancement - Indian River is very close to Vancouver and is presently protected from angler overuse by the access (boat/trailbike/foot or truck/4 x 4 in summer months). The watershed is recovering from years of logging and will improve for both fish and anglers until the next logging pass in the distant future. The Indian provides a rather unique trout/salmon angling situation in our Lower Mainland bag of tricks. These facts plus the declining trout stocks make enhancement important.

(4) Management Strategy -

a) Fish Culture

Steelhead - improvement of winter run and possibly summer run to provide a year-round uncrowded "semi-wilderness" fishery. Primary move would be to quickly bolster runs by planting smolts. Fry introductions could be possible in upper river above falls and in some tributaries (see (b) below).

Appendix 1 (cont'd).

Cutthroat - Indian River facility would be used to improve the Indian River/Estuary sport fishery for cutthroat. It could also have major importance as a source of cutthroat smolts and fry to outplant to stream sites on Indian Arm and the North Shore of Vancouver. These outplants would primarily bolster marine beach fisheries for cutthroat. These fisheries are growing in popularity around Vancouver. (On the North Shore other opportunities for improving cutthroat stocks exist but may not prove capable). It is doubtful if Capilano hatchery will be able to produce many cutthroat, if any. Production of steelhead/cutthroat from the BCIT facility on the Seymour River will likely only be capable of servicing this river.

b) Instream Improvement - about 9 km upstream from the estuary there is a difficult obstruction (barrier?) to upstream movement of anadromous salmon and trout. Modification of this barrier would expose an additional 20-25 km of prime spawning/rearing habitat for sea-run fish. It would also provide more angling water to steelhead and cutthroat anglers. Barrier modification appears feasible (requires a Don Hjorth inspection).

c) Future Habitat Protection Problems - GVWD has an old water licence which allows them to remove and use most of the flow in Hixon Creek, a lower Indian River tributary. They are planning to divert Hixon flow in the future (five years?). These plans could possibly be altered by negotiations with fishery agencies or by public opinion. I don't think fishery agencies have decided their stance on this project. (Chuck Chestnut of BCIT is very familiar with the Indian watershed and he is concerned about affects of flow reduction on the lower Indian, ie. temperature, angler use?)

Appendix 2. Proposed Indian River hatchery, DFO minutes of meeting, File No. 5830-13-16, July 16, 1981.

SUBJECT: Proposed Indian River Hatchery

A. Groundwater

- Discussed recent groundwater testing results: (1) Well No. 1 had acceptable water quality; however, quantity (50 gpm) was not sufficient; (2) Well No. 2 was not acceptable, due to high iron content.

- It was agreed to undertake a new test drilling program to obtain better quality groundwater. It is proposed to drill a series of 6" holes near the river, and moving downstream from Well No. 2 towards Hixon Creek.

B. Fish Production Goals

Production goals for various species, as previously determined:

| | | |
|---|---|---|
| Chinook | - | 50,000 adults |
| Chum | - | 100,000 adults |
| Pink | - | 200,000 adults |
| Coho | - | 50,000 adults |
| Steelhead | - | 1,000 adults |
| | + a possible release of | 100,000 unfed fry |
| Cutthroat | - | 10,000 adults |
| | + a possible release of | 100,000 unfed fry |

C. Incubation and Rearing Techniques

(a) Steelhead and Cutthroat

(1) Incubation - Heath tray.

(2) Intermediate rearing - Cap. troughs.

(3) Rearing - raceways similar to Chehalis Hatchery raceways.

(b) Chinook and Coho

(1) Incubation - Heath trays.

(2) Chinook rearing - combination rearing/holding ponds similar to Robertson Creek. Include starter ponds and provision for fish sales.

(3) Coho rearing - dirt rearing channel similar to Robertson Creek (area criteria). Provide Capilano troughs to separate different coho stocks.

Appendix 2 (cont'd).

(c) Chum

(1) Incubation - Atkins boxes to shallow keeper channels.

(2) Rearing - provide concrete raceways, with fry collection facilities. Capacity to raise fry to five to six days before transfer to sea pens for final rearing. Raceways would also double as adult holding ponds. First phase, build sea-pen capacity for full chum production. Use 50 percent sea-pen capacity for chum, and 50 percent for pink.

- When chum facility is up to full production, either provide more sea-pen capacity or additional fresh water rearing capacity.

(d) Pink

(1) Incubation - Atkins boxes to shallow keeper channels, with collection facilities at end.

(2) Rearing - 50 percent of full production into sea pens. Balance straight release.

D. Other Facilities

(a) Residences - could be up to three required: (1) Manager, (2) Assistant Manager, and (3) Crew Residence. Latter two could be combined.

(b) Laboratory Officer.

(c) Workshop, Storage.

(d) Food Storage.

Appendix 3. Preliminary sizing of Indian River project, DFO memorandum, File No. 5830-85-515-1, Feb. 8, 1982.

SUBJECT: Preliminary Sizing of Indian River Project

This memo is the response to a request from SEP Engineering (Wild to Shepherd) to provide gross container sizing for a proposed hatchery on the Indian River in Indian Arm. This is not to be considered a formal design memo.

1. Project Development

Several particulars about this project need to be resolved before any detailed bio-engineering design work can be undertaken.

- Target numbers for each species have been identified (Meeting minutes from July 16, 1981 on file 5830-13-16) but there is still considerable controversy as to just what type of target fishery (commercial, sport, native, mixed) is suitable for this area. Justification for a project at Indian must be based on manageability, which will obviously affect the species mix.

- The Capilano hatchery may increase production considerably by using the old filter beds as rearing raceways and thus become a potential vehicle for fry outplanting to the Indian, precluding the need for a coho and chinook hatchery.

  Certain site constraints are also holding up commitment to formal site acceptance and design calculations.

- The Indian River watershed is plagued with high iron content in both the surface and groundwater. The low samples which occur periodically may be only temporal or low volume anomalies, therefore any 'clean' source in this system must undergo extensive, long term, high rate testing before any confidence can be placed in it.

- The surface water and some groundwaters of Indian are extremely soft and of low pH. These conditions have been linked with coagulated yolk sac disease at the Indian River Pilot hatchery (Fedorenko to Wilson memo, February 25, 1980 on file 5830-13-16).

- The temperature profile of the river water is presently (1981-82) being monitored by New Projects with a Ryan thermograph. Such a profile for any potential groundwater source must also be collected for at least a year before more accurate design calculations can be made.

2. Biological Requirements

Preliminary design calculations are summarized in Appendix Tables 3-1 to 3-5 with a container and flow summary in Appendix Table 3-6. Enhancement strategies are the standard methods for each species, as outlined in the minutes of the July 16, 1981 meeting (file 5830-13-16), with certain

Appendix 3 (cont'd).

exceptions or potential options as outlined below. The tables are therefore not necessarily a profile of the proposed facility.

a) Steelhead and Cutthroat: Responsibility for container selection and sizing for these species lies solely with the B.C. Fish and Wildlife Branch. However, for preliminary purposes, Heath tray incubation, Capilano trough and raceway rearing are assumed. A second additional option for fry outplant release of steelhead and cutthroat has also been calculated. More detailed or revised criteria will not be expected from B.C. Fish and Wildlife until the project concept problems are resolved. Special adult containers are usually required for trout.

b) Chinook: Heath tray incubation will probably be followed by ponding into the rearing raceways. However, Capilano trough calculations are provided for reference. Adult holding is in the same raceways.

c) Coho: Heath tray incubation ponding to Capilano troughs. Final rearing will start out in gravel channels but may be shifted to chum sea pens over winter. No sizing is required since the chum pens will more than adequately accommodate all the coho if that option is chosen. Adult holding in chinook raceways.

d) Chum: Eyed in Atkins boxes, then planted in keeper channels. If suitable mooring can be found, fry will be collected in chamber at bottom of keepers and transported to sea pens. Sea pen requirement is 14 (450K/pen for 6,250K fry) each 10 m x 10 m with 3 m deep nets (includes 1 m above water surface). If no suitable mooring can be developed, standard Japanese freshwater rearing raceways will be used. Adult holding in chinook raceways.

e) Pink: Atkins boxes and straight release from keeper channels. Some sea pen rearing may be attempted but preliminary results from work at Quinsam are not encouraging. Adult holding in raceways.

3. Support Requirements

a) Water treatment - aeration, stripping to acceptable gas levels; there may be a need for $Ca\ Cl_2$ drip system.
b) Hatchery building - offices (3), workshop, laboratory, dry storage.
c) Crew residences - two houses and multi-bedroom residence.
d) Equipment storage building for boats, nets, etc.
e) Shore side storage, launch area for sea pens.
f) Feed storage - rough calculation based on feed conversion 2.0:1, OMP:Fish. Sized for all fish = 28,390 kg fish x 2 kg feed/kg fish = 56,780 kg feed @ 22.7 kg feed/bag = 2,500 bags of feed @ 30 bags/$m^2$ of floor space = 84 $m^2$ + 4$m^2$ aisle = 88 $m^2$ freezer floor space.

Appendix Table 3-1. Production objectives for Indian River project.

| SPECIES | EGGS | % EGGS-EYED | EYED EGGS | % EGG-FRY | FRY | % FRY-FINGER | FINGER-LINGS | % FRY SMOLT | RELEASED SMOLTS | % EGG-ADULT | ADULT RETURN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CHINOOK | 2,315K | - | - | 90 | 2,083K | 90 | 1,875 | 80 | 1,667K | 2.16 | 50K |
| CHUM | 6,944K | 95 | 6,597K | 90 | 6,250K | | | | 5,625K | 1.44 | 100K |
| COHO | 494K | - | - | 90 | 444K | 90 | 400K | 75 | 333K | 10.13 | 50K |
| PINK | 10,000K | 90 | 9,000K | 80 | 8,000K | | | 80 | 6,400K | 2.0 | 200K |
| STEELHEAD[I] | 48K | - | - | 75 | 36K | 90 | 32K | 70 | 25K | 2.1 | 1K |
| STEELHEAD[II] | 133K | - | - | 75 | 100K | - | - | - | - | - | - |
| CUTTHROAT[I] | 72K | - | - | 80 | 58K | 90 | 52K | 70K | 70K | 5.6 | 10K |
| CUTTHROAT[II] | 125K | - | - | 80 | 100K | - | - | - | - | - | - |

Appendix Table 3-2. Incubation sizing for Indian River project.

| STOCK | SPECIES | EGGS | UNIT TYPE | EGGS/ UNIT | UNITS | UNITS/ LINE | LINES | FLOW/ LINE (LPM) | FLOW (REG/FLUSH) (LPM) |
|---|---|---|---|---|---|---|---|---|---|
| INDIAN | CHINOOK | 2,315K | Heath | 5K | 463 | 8 | 58 | 15/19 | 870/1,102 |
| | CHUM | 6,944K | Atkins | 150K | 47 | 4 | 12 | 30 | 360 |
| | CHUM | 6,597K | Keeper | 15K/$m^2$ | 220m | 44m | 5 | 150/450 | 600/2,250 |
| | COHO | 494K | Heath | 8.5K | 59 | 8 | 8 | 15/ 19 | 120/ 152 |
| | PINK | 10,000K | Atkins | 150K | 67 | 4 | 17 | 30 | 510 |
| | PINK | 9,000K | Keeper | 15K/$m^2$ | 300m | 44m | 7 | 150/450 | 1,050/3,150 |
| | STEELHEAD$^{I}$ | 48K | Heath | 10K | 5 | 8 | 1 | 15/ 19 | 15/ 19 |
| | STEELHEAD$^{II}$ | 133K | Heath | 10K | 14 | 8 | 2 | 15/ 19 | 30/ 38 |
| | CUTTHROAT$^{I}$ | 179K | Heath | 10K | 18 | 8 | 3 | 15/ 19 | 45/ 57 |
| | CUTTHROAT$^{II}$ | 125K | Heath | 10K | 13 | 8 | 2 | 15/ 19 | 30/ 38 |

Appendix Table 3-3. Initial rearing sizing for Indian River project.

| STOCK | SPECIES | FRY | FINGER-LINGS | UNIT TYPE | FRY/ UNIT | UNITS | UNITS/ LINE | LINES | FLOW/ LINE (START/END) | FLOW (START/END) (LPM) |
|---|---|---|---|---|---|---|---|---|---|---|
| INDIAN | CHINOOK | 2,083K | 1,875K | CAPILANO | 57K | 37 | 2 | 19 | 120/240 | 2,280/4,560 |
| | COHO | 444K | 400K | CAPILANO | 57K | 8 | 2 | 4 | 120/240 | 480/ 960 |
| | STEELHEAD[I] | 36K | 32K | CAPILANO | 10K | 4 | 2 | 2 | 120/240 | 240/ 480 |
| | CUTTHROAT[I] | 143K | 129K | CAPILANO | 10K | 15 | 2 | 8 | 120/240 | 960/1,920 |

Appendix Table 3-4. Rearing container sizing for Indian River project.

| STOCK | SPECIES | FISH (START/END) | FISH SIZE (START/END) | BIOMASS (START/END) (GRAMS) | UNIT TYPE | DIMENSIONS L/W/D/wD | LOAD RATE[a] | UNITS | FLOW LOADING (START/END)[a] | FLOW (START/END) (LPM) |
|---|---|---|---|---|---|---|---|---|---|---|
| INDIAN | CHINOOK | 1,875K/1,667K | .4/ 5 g | 750/8,335 | Raceway | 40/4/1.7/1.2 | 15 kg/$m^3$ | 3 (556 $m^3$) | .8 Kg/LPM | 10,419 |
| | CHUM | 6,250K/5,625K | .4/ 1 g | 2,500/5,625 | Raceway | 40/4/1.7/1.2 | 15 K/$m^2$ | 6 (960 $m^3$) | .5 Kg/LPM | 11,250 |
| | COHO | 400K/ 333K | .3/25 g | 120/8,325 | Channel | 7 $m^2$ x S | 23 kg/$m^3$ | 52m (362 $m^3$) | 1 Kg/LPM | 8,325 |
| | STEELHEAD[I] | 32K/ 25K | .2/55 g | 6.4/1,375 | Raceway | 20/2/1.5/1.2 | 32 kg/$m^3$ | 1 (43 $m^3$) | 1 Kg/LPM | 1,375 |
| | CUTTHROAT[I] | 129K/ 86K | .2/55 g | 25.8/4,730 | Raceway | 20/2/1.5/1.2 | 32 kg/$m^3$ | 3 (148 $m^3$) | 1 Kg/LPM | 4,730 |

[a] Load rates from LOAD model based on expected conditions.

Appendix Table 3-5. Adult holding for Indian River project.

| STOCK | SPECIES | EGGS | FECUN-DITY | FEMALE DONORS | TOTAL DONORS | WEIGHT/ DONOR (kg) | DONOR BIOMASS (kg) | FLOW (LPM) | VOLUME ($m^3$) | DIMENSIONS/ UNIT | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INDIAN | CHINOOK | 2,315K | 5,000 | 463 | 741 | 5 | 3,704 | 3,087 | 116 | 40/4/1.7/1.5 | .5 |
| | CHUM | 6,944K | 2,800 | 2,480 | 3,968 | 5 | 19,840 | 16,533 | 620 | 40/4/1.7/1.5 | 2.5 |
| | COHO | 494K | 2,500 | 198 | 316 | 3 | 949 | 790 | 30 | 40/4/1.7/1.5 | .1 |
| | PINK | 10,000K | 1,500 | 6,667 | 10,667 | 2 | 21,333 | 17,778 | 667 | 40/4/1.7/1.5 | 3 |
| | STEELHEAD | 181K | 4,000 | 45 | 72 | 3 | 217 | 181 | 7 | 10/1/1.1/1.0 | 1 |
| | CUTTHROAT | 204K | 1,100 | 185 | 297 | 1 | 326 | 272 | 10 | 10/1/1.1/1.0 | 1 |
| | TOTAL REQUIRED | | | | | | | 38,641 | | | 6.1 |
| | TOTAL AVAILABLE | | | | | | | | | | 9.0 |

Appendix Table 3-6. Container and maximum flow summary for Indian River project.

| | UNITS | LINES | MAXIMUM FLOW |
|---|---|---|---|
| INCUBATION | | | |
| Heath Trays | 572 | 72 | 1,368 LPM |
| Atkins Boxes | 114 | 29 | 870 LPM |
| Keeper Channels | 24 | 12 | 5,400 LPM |
| | | | 7,638 LPM |
| REARING | | | |
| Capilano Troughs | 64 | 32 | 7,680 LPM |
| Raceways (40 x 4 x 1.7) | 9 | 9 | 21,669 LPM |
| Raceways (20 x 2 x 1.5) | 4 | 4 | 6,105 LPM |
| Channel (52 m x 7 $m^2$) | 1 | 1 | 8,325 LPM |
| | | | 43,779 LPM |
| HOLDING | | | |
| Raceways (40 x 4 x 1.7) | 7 | 7 | 38,188 LPM |
| Boxes (10 x 1 x 1) | 2 | 2 | 500 LPM |
| | | | 38,688 LPM |